JC10 Rec'd PCT/PTO 11 JAN 2002

FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER
GRP-0009

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR
10/030675

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/DK00/00376	**7 July 2000**	**12 July 1999**

TITLE OF INVENTION
DIRECTIONAL HIGH-VOLTAGE DETECTOR

APPLICANT(S) FOR DO/EO/US
OLUF PETER KAAD JOHANSEN

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☐ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☐ Other items or information:

"Express Mail" mailing label number EL 914109784US
Date of Deposit January 11, 2002
I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231.

Jennifer Matson
(Typed or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee)

PCTUS1/REV03

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U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
10/030675	PCT/DK00/00376	GRP-0009

24. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

	CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).	**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	22 - 20 =	2	x $18.00	**$36.00**	
Independent claims	7 - 3 =	4	x $84.00	**$336.00**	
Multiple Dependent Claims **(check if applicable)**.			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,262.00**	
☒ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$631.00**	
SUBTOTAL =				**$631.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$631.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).** ☐				**$0.00**	
TOTAL FEES ENCLOSED =				**$631.00**	
				Amount to be: refunded	$
				charged	$

a. ☐ A check in the amount of ____________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. **06-1130** in the amount of **$631.00** to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **06-1130** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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SIGNATURE

Daniel F. Drexler
NAME

47,535
REGISTRATION NUMBER

January 11, 2002
DATE

10/030675
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Express Mail Label #EL914109784US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

IN RE APPLICATION OF: OLUF PETER KAAD JOHANSEN

FOR: DIRECTIONAL HIGH-VOLTAGE DETECTOR

PRELIMINARY AMENDMENT

The Assistant Commissioner of
Patents and Trademarks
Washington, DC 20231

Dear Sir:

Prior to the Examiner acting in the above-referenced application, please preliminary amend the abstract and claims as follows:

IN THE CLAIMS:

Please amend the following re-written claims as follows:

1. (Amended) A directional high-voltage detector for a high-voltage conductor comprising:

at least one voltage-measuring circuit for measuring voltage in said conductor,

at least one current-measuring circuit for measuring current in said conductor.

and means for determining an energy flow in the conductor on the basis of measurements made by said voltage-measuring circuit and said current –measuring circuit.

2. (Amended) The directional high-voltage detector according to claim 1, wherein the voltage-measuring circuit comprises at least one capacitive detector which forms a capacitive coupling with the conductor.

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Jennifer Watson
(Typed or printed name of person mailing paper or fee)

(Signature of person mailing paper or fee)

3. (Amended) The directional high-voltage detector according to claim 2, wherein the capacitive detector comprises a metal plate covering a section of the conductor.

4. (Amended) The directional high-voltage detector according to claim 3, wherein edges of the plate are bent away from the conductor.

5. (Amended) The directional high-voltage detector according to claim 3, further comprising a dielectric material disposed between the metal plate and the conductor wherein the material is silicone and covers a surface of said detector.

6. (Amended) The directional high-voltage detector according to claim 5, wherein the silicone layer serves as an isolation layer between high-voltage potentials in said detector and an exterior.

7. (Amended) The directional high-voltage detector according to claim 1, further comprising at least one capacitor connected serially to a capacitive coupling and a reference potential.

8. (Amended) The directional high-voltage detector according to claim 7, wherein the reference potential is a ground potential of at least one conductor.

9. (Amended) The directional high-voltage detector according to claim 1, wherein the current-measuring circuit comprises at least one detector for measuring a magnetic field generated by the current in the conductor.

10. (Amended) The directional high-voltage detector according to claim 9, wherein the magnetic field detector comprises two hall elements.

11. (Amended) The directional high-voltgage detector according to claim 9, wherein supply lines for the magnetic field detector and a calculation circuit comprise shields against magnetic fields.

12. (Amended) A directional high-voltage detector for a high-voltage conductor comprising:

at least one voltage-measuring circuit for measuring voltage in said conductor by means of at least one capacitive detector,

at least one current-measuring circuit for measuring current in said conductor by means of at least one magnetic field detector,

and means for determining an energy flow in the conductor on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit.

13. (Amended) The directional high-voltage detector according to claim 12, wherein said means for determining said energy flow determine an energy flow direction on the basis of polarities of the current and voltage between two preceding zero-crossings of the voltage.

14. (Amended) An apparatus for measuring on a high-voltage conductor comprising:

at least one voltage-measuring circuit for measuring voltage in said conductor by means of at least one capacitive detector,

at least one current-measuring circuit for measuring current in said conductor by means of at least one magnetic field detector,

and means for determining an energy flow in the conductor on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit.

15. (Amended) An apparatus for measuring on a conductor comprising:

at least one voltage-measuring circuit for measuring voltage in said conductor by means of at least one capacitive detector,

at least one current-measuring circuit for measuring current in said conductor by means of at least one magnetic field detector,

and means for determining an energy flow in the conductor on the basis of measurements by said voltage-measuring circuit and said current measuring-circuit.

16. (Amended) The apparatus for measuring on a conductor according to claim 15, wherein the magnetic field detector comprises at least one magnetic-resistant detector.

17. (Amended) A high-voltage fault detector for a high-voltage conductor comprising means for determining a direction of an energy flow in said conductor.

18. (Amended) A method for determining a direction of an energy flow in a high-voltage conductor comprising at least one voltage-measuring circuit measuring voltage in said conductor by means of at least one capacitive detector, at least one current-measuring circuit measuring current in said conductor by means of a magnetic field detector and a calculation circuit calculating a direction value derived from the measured voltage and current.

19. (Amended) The method for determining the direction of an energy flow in a high-voltage conductor according to claim 18, wherein the calculation circuit calculates the direction value on the basis of polarities of the current and the voltage between two preceding zero-crossings of the voltage.

20. (Amended) A method for determing a direction of an energy flow in a high-voltage conductor, comprising at least one current-measuring circuit measuring current, at least one voltage-measuring circuit measuring voltage, wherein a calculation circuit divides said voltage into a number of samples within a period of time and wherein said calculation circuit compares a first voltage sample value numerically larger than a constant value with immediately preceding values to determine the sample value closest to zero voltage.

21. (Amended) The method for determining the direction of the energy flow in a high-voltage conductor according to claim 20, wherein the calculation circuit calculates the direction value on the basis of polarities of the current and voltage between two preceding zero-crossings of the voltage.

22. (Amended) The method for determining the direction of the energy flow in a high-voltage conductor according to claim 21, wherein the constant value exceeds a noise level.

IN THE ABSTRACT:

Please add the following Abstract:

ABSTRACT:

Directional high-voltage detector for a high-voltage conductor comprising at least one voltage-measuring circuit for measuring the voltage in said conductor, at least one current-measuring circuit for measuring the current in said conductor and means for determining the energy flow in the conductor on the basis of the measurements made by said voltage-measuring circuit and said current-measuring circuit.

REMARKS

Applicant requests entry of the above-identified amendments which conform the claims to U.S. practice. No new matter is being introduced by this Amendment as antecedent support is set forth in the specification and the original claims.

Prosecution on the merits is respectfully requested.

If there are any charges with respect to this Amendment or otherwise, please charge them to Deposit Account No. 06-1130 maintained by Applicant's attorneys.

Respectfully submitted,
OLUF PETER KAAD JOHANSEN

CANTOR COLBURN LLP
Applicant's Attorney

By: ______________________
Daniel F. Drexler
Registration No. 47,535
Customer No. 23413

Date: January 11, 2002
Telephone: 860-286-2929

VERSION WITH MARKINGS TO SHOW CHANGES MADE

1. (Marked Up/Amended) A d[D]irectional high-voltage detector [(5)] for a high-voltage conductor [(10)] comprising:

[·] at least one voltage-measuring circuit for measuring voltage in said conductor [(10)],

[·] at least one current-measuring circuit for measuring current in said conductor [(10)].

[·] and means for determining [the] an energy flow in the conductor [(10)] on the basis of measurements made by said voltage-measuring circuit and said current – measuring circuit.

2. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 1, [characterised in that] wherein the voltage-measuring circuit comprises at least one capacitive detector [(11)] which forms a capacitive coupling with the conductor [(10)].

3. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 2, [characterized in that] wherein the capacitive detector [(11)] comprises a metal plate [(20)] covering a section of the conductor [(10) partially or totally].

4. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 3, [characterized in that the] wherein edges [or corners] of the plate are bent away from the conductor [(10)].

5. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 3 [1], [characterized in that the] further comprising a dielectric material disposed between the metal plate [(20)] and the conductor wherein the material [(10)] is silicone and cover[ing]s [the] a surface of said detector [partially or totally].

6. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 5, [characterized in that] wherein the silicone layer serves as an isolation layer between [the] high-voltage potentials in said detector and [the] an exterior[, respectively].

7. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 1, [characterized in that] further comprising at least one capacitor [(12) is] connected serially to [the] a capacitive coupling [(11)] and a reference potential [(13), respectively].

8. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 7, [characterized in that] wherein the reference potential [(13)] is [the] a ground potential of at least one conductor.

9. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 1, [characterized in that] wherein the current-measuring circuit comprises at least one detector [(14)] for measuring [the] a magnetic field generated by the current in the conductor [(10)].

10. (Marked Up/Amended) The d[D]irectional high-voltage detector according to claim 9 [1], [characterized in that] wherein the magnetic field detector [14] comprises two hall elements [15, 16].

11. (Marked Up/Amended) The d[D]irectional high-voltgage detector according to claim 9 [1], [characterized in that the] wherein supply lines for the magnetic field detector [(15, 16)] and [the] a calculation circuit [(17)] comprise shields [(21)] against magnetic fields.

12. (Marked Up/Amended) A d[D]irectional high-voltage detector for a high-voltage conductor comprising:

[·] at least one voltage-measuring circuit for measuring voltage in said conductor [(10)] by means of at least one capacitive detector [11],

[·] at least one current-measuring circuit for measuring current in said conductor [(10)] by means of at least one magnetic field detector [14, 15, 16],

[·] and means [17] for determining [the] an energy flow in the conductor [(10)] on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit.

13. (Marked Up/Amended) The d[D]irectional] high-voltage detector according to claim 12, [characterized in that] wherein said means for determining said energy flow [(17)] determine [the] an energy flow direction on the basis of [the] polarities of the current and voltage between two preceding zero-crossings of the voltage.

14. (Marked Up/Amended) An a[A]pparatus for measuring on a high-voltage conductor [(10)] comprising:

[·] at least one voltage-measuring circuit for measuring voltage in said conductor [(10)] by means of at least one capacitive detector [(11)],

[·] at least one current-measuring circuit for measuring current in said conductor [(10)] by means of at least one magnetic field detector [(14, 15, 16)],

[·] and means for determining [the] an energy flow in the conductor [(10)] on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit.

15. (Marked Up/Amended) An a[A]pparatus for measuring on a conductor [(10)] comprising:

[·] at least one voltage-measuring circuit for measuring voltage in said conductor [(10)] by means of at least one capacitive detector [(11)],

[·] at least one current-measuring circuit for measuring current in said conductor [(10)] by means of at least one magnetic field detector [(14, 15, 16)],

[·] and means for determining [the] an energy flow in the conductor [(10)] on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit.

16. (Marked Up/Amended) The a[A]pparatus for measuring on a conductor [(10)] according to claim 15, [characterized in that] wherein the magnetic field detector [(14)] comprises at least one magnetic-resistant detector [(15, 16)].

17. (Marked Up/Amended) A h[H]igh-voltage fault detector for a high-voltage conductor [(10) wherein said detector comprises] comprising means for determining [the] a direction of an energy flow in said conductor [(10)].

18. (Marked Up/Amended) A m[M]ethod for determining [the] a direction of an energy flow in a high-voltage conductor [wherein] comprising at least one voltage-measuring circuit measur[es]ing voltage in said conductor by means of at least one capacitive detector, at least one current-measuring circuit measur[es]ing current in said conductor by means of a magnetic field detector and a calculation circuit calculating a direction value derived from the measured voltage and current.

19. (Marked Up/Amended) The m[M]ethod for determining the direction of an energy flow in a high-voltage conductor according to claim 18, [characterized in that] wherein the calculation circuit calculates the direction value on the basis of [the] polarities of the current and the voltage between two preceding zero-crossings of the voltage.

20. (Marked Up/Amended) A m[M]ethod for determing [the] a direction of an energy flow in a high-voltage conductor, [wherein] comprising at least one current-measuring circuit measur[es]ing current, at least one voltage-measuring circuit measur[es]ing voltage, wherein a calculation circuit divides said voltage into a number of samples within a period of time and wherein said calculation circuit compares [the] a first voltage sample value numerically larger than a constant value with [the] immediately preceding values to determine the sample value closest to zero voltage.

21. (Marked Up/Amended) The m[M]ethod for determining the direction of the energy flow in a high-voltage conductor according to claim 20, [characterized in that]

wherein the calculation circuit calculates the direction value on the basis of [the] polarities of the current and voltage between two preceding zero-crossings of the voltage.

22. (Marked Up/Amended) The m[M]ethod for determining the direction of the energy flow in a high-voltage conductor according to claim 21, [characterized in that] wherein the constant value exceeds [the] a noise level.

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DIRECTIONAL HIGH-VOLTAGE DETECTOR

Field of the invention

The invention relates to a directional high-voltage detector according to the preamble of claims 1 and 12, an apparatus for measuring on a high-voltage conductor according to the preamble of claim 14, an apparatus for measuring on a conductor according to the preamble of claim 15, a high-voltage fault detector according to the preamble of claim 17 and method for determining the direction of an energy flow in a high-voltage conductor according to the preamble of claims 18 and 20.

Background of the invention

A high-voltage distribution or transmission system normally comprises numerous conductors directly or indirectly connecting a number of electrical energy generators and electrical energy consumers. The conductors in the distribution system can be in the form of overhead power lines and underground power cables or combinations thereof. The electrical energy generators will normally be power plants such as nuclear, water or coal burning electrical power plants but also wind turbine plants and similar kinds of plants are possible.

The energy consumers may be all kinds of electrical energy consumers in society such as electrical machinery in factories, electrical light in offices and electrical heating apparatuses in private households etc. Other

kinds of electrical energy consumers are hospitals where e.g. life support machines are driven by electrical energy and airports where traffic system computers are also driven by electrical energy.

The dependency by a society on a reliable electrical power supply, and especially a reliable distribution or transmission system, is indisputable and even shorter interruptions of the supply can have a significant economic effects on society and also result in loss of human lives.

The transmission and distribution system is particularly vulnerable to different kind of faults due to its size. In order to detect and locate faults in a fast and reliable way, it is necessary to be able to monitor the system continuously.

So far, monitoring has been performed by detectors shattered along the transmission and distribution system, with communication links to a monitoring center. The detectors normally read the voltage or current in the system on the basis of different kinds of measuring methods such as inductive or capacitive methods. Combinations of inductive and capacitive detectors measuring both voltage and current are also known.

The detectors report any detection of significant changes in the voltage or current indicating that a fault has occurred in the transmission and distribution system. A major problem is, however, that they lack the capability of indicating where the fault has occurred.

At the same time, known detectors are voluminous and heavy in addition to being quite expensive. Especially detectors using measuring methods including transformers or Rukowski coils will suffer from these drawbacks.

Summary of the invention

When, as stated in claim 1, a directional high-voltage detector for a high-voltage conductor comprising at least one voltage-measuring circuit for measuring voltage in said conductor, at least one current-measuring circuit for measuring current in said conductor and means for deriving the energy flow in the conductor on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit, it is possible not only to detect a fault in the conductor but also to indicate in which direction it has occurred from the detector.

This is an important advantage over prior art because it makes it possible to locate faults in the conductor in a quick manner and thereby restore the transmission and distribution system to its normal functional way at a sooner point.

When, as stated in claim 2, the voltage-measuring circuit comprises at least one capacitive detector forming a capacitive coupling with the conductor, it is possible to measure high-voltage without creating a physical connection between the conductor and the measuring circuit. This is very important due to the high-voltage level being measured.

When, as stated in claim 3, the capacitive detector comprises a plate covering a section of the conductor partially or totally, it is possible to create a capacitive coupling which is easy to design and adapt to different kinds of conductors or voltage values. The size of the plate may easily be changed as may the distance between the plate and the conductor.

When, as stated in claim 4, the edges or corners of the plate are bent away from the conductor, it is possible to raise the breakdown voltage for the capacitive detector by increasing the distance from the plate to the conductor in places most likely exposed to a breakdown.

When, as stated in claim 5, the dielectric material between the plate and the conductor is silicone, which covers the surface of said detector partially or totally, it is possible to create a capacitor with an accurately defined dielectric constant.

When, as stated in claim 6, the silicone layer serves as an isolation layer between the high-voltage potentials in said detector and the exterior, it is possible to protect e.g. human beings from the danger of life-threatening electric shock.

The silicone also protects the circuits of the detector from humidity and aggressive gasses.

When, as stated in claim 7, at least one capacitor is connected serially to the capacitive coupling and a reference potential respectively, it is possible to create a purely capacitive voltage divider.

Thereby, the output voltage from the divider will be without phase displacement which makes any adjustments to the measured voltage or current values of the calculation superfluous while also making it possible to detect very low voltage levels.

The measured value will moreover be a real-time image of the conductor voltage value and polarity.

When, as stated in claim 8, the reference potential is the ground-symmetrical potential of at least one conductor, it is possible to measure the current proportionately to a fixed reference, ensuring a high degree in the accuracy of measurement.

When, as stated in claim 9, the current-measuring circuit comprises at least one detector for measuring of the magnetic field generated by the current in the conductor, it is possible to measure the current without any physical connection between the conductor and the measuring circuit.

The measured value will also be a real-time image of the value and polarity of the current in the conductor.

When, as stated in claim 10, the magnetic field detector comprises two hall elements, it is possible to cancel out an interference field by adding the two detected values to the interference field. The first hall element will detect the interference field in one direction and the second hall element will detect the interference field in the opposite direction.

Hereby, it is possible to e.g. cancel out a magnetic field from a conductor placed in proximity to a conductor equipped with a directional high-voltage detector which must not affect the actual reading of the detector.

When, as stated in claim 11, the supply lines for the magnetic field detectors and the calculation circuit comprise shields against magnetic fields, it is possible to avoid reading errors. The measured voltage is only a few milivolts and occurs in a very powerful electromagnetic field only a few milimeters from the high voltage in the conductor. This may easily result in reading errors as the slightest and seemingly insignificant capacitive coupling between the various components/supply lines and the conductor results in reading errors of the current due to the capacitive coupling of the conductor voltage. Furthermore, the electromagnetic fields from other conductors may also create reading errors.

When, as stated in claim 12, a directional high-voltage detector for a high-voltage conductor comprising at least one voltage-measuring circuit for measuring a voltage in said conductor by means of at least one capacitive detector, at least one current-measuring circuit for measuring current in said conductor by means of at least one magnetic field detector and means for deriving the energy flow in the conductor on the basis of measurement by said voltage-measuring circuit and said current-measuring circuit, it is possible to determine the energy flow in the conductor in an advantageous manner.

When, as stated in claim 13, said means determine the energy flow direction on the basis of the polarity of the current and voltage between two preceding zero-crossings of voltage, it is possible to determine the direction of the energy flow in a fast and reliable way. Especially since the measured voltage and current values are real-time images of the conductor voltage and current in value and polarity.

When, as stated in claim 14, an apparatus for measuring on a high-voltage conductor comprising at least one voltage-measuring circuit for measuring voltage in said conductor by means of at least one capacitive detector, at least one current-measuring circuit for measuring current in said conductor by means of a magnetic field detector and means for determining the energy flow in the conductor on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit, it is possible to determine the direction of an energy flow in a high-voltage conductor.

When, as stated in claim 15, an apparatus for measuring on a conductor comprising at least one voltage-measuring circuit for measuring voltage in said conductor by means of at least one capacitive detector, at least one current-measuring circuit for measuring current in said conductor by means of at least one magnetic field detector and means for determining the energy flow in the conductor on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit, it is possible to determine the direction of an energy flow in a conductor.

When, as stated in claim 16, the magnetic field detector comprises at least one magnetic-resistant detector it is possible to measure a small current intensity in an advantageous manner.

When, as stated in claim 17, a high-voltage fault detector for a high-voltage conductor, said detector comprising means to determine the direction of an energy flow in said conductor, it is possible not only to detect a fault in the high-voltage conductor but also to determine in which direction it has occurred from the detector.

Drawings

The invention will be described below with reference to the drawings in which

fig. 1 illustrates a transmission and distribution system provided with a directional high-voltage detector according to the invention,

fig. 1a illustrates part of a transmission and distribution system in detail,

fig. 2 illustrates the basic elements in a directional high-voltage detector,

fig. 3 illustrates a preferred embodiment of a directional high-voltage detector according to the invention,

fig. 4 illustrates the preferred embodiment of a directional high-voltage detector seen from another angle,

fig. 5 illustrates a representation of voltage and current values,

fig. 6 illustrates a fraction of the representation centered around a zero-crossing of the voltage.

Detailed description

Referring to fig. 1, a transmission and distribution system 2 is shown consisting of overhead power lines or underground power cables, connecting one or more energy producers 1 with energy consumers or loads enabling a transfer of electrical energy. The transfer of electrical energy will normally be high-voltage, and especially AC voltage, to ensure a minimum of energy loss during the transport through the transmission and distribution system. Also, the voltage will normally be a 3-phased voltage, i.e. the power lines or cables consist of at least 3 conductors.

The lines or cables of the transmission and distribution system are of considerable length which makes it vulnerable to faults of different kinds. A short-circuit 6 in the system may occur as a result of e.g. animal attacks, landslides and construction machinery working in the wrong places. Deterioration of the cable isolation can be another reason for a short-circuit. In order to determine the location of the fault, a number of directional detectors 5 are placed along the conductors of the transmission and distribution system. On the basis of voltage and current measurements, the detectors will be able to determine the direction of the energy flow in the conductor. When a fault occurs, the directional detectors will point to the location of the fault to which energy is flowing.

Referring to fig. 1a, a possible fault situation in a transmission and distribution system is illustrated. The transmission and distribution system includes a high-voltage cable or line Hv and a number of high-voltage transformers Tr which have each been connected to one or more loads 4 on the low-voltage side. In this fault situation, a short-circuit 6 has occurred on the high-voltage side of a transformer Tr. The detectors 5 placed along the high-voltage cable or line all point to the location of the short-circuit towards which energy is flowing.

Referring to fig. 2, a directional high-voltage detector 5 is displayed together with a conductor 10 in a transmission and distribution system 2. The directional detector comprises a voltage-measuring circuit with a capacitive detector 11 and a current-measuring circuit with one or more magnetic field detectors 14. The capacitive detector 11 forms a voltage divider together with a capacitor 12. The capacitor 12 is also connected to a reference point 13 which may be chosen as the symmetrical point of origin of e.g. a 3-phase cable, which equals the ground potential.

The divided measured voltage value and the measured current value are fed to a calculation circuit 17 which calculates the directional value of the energy flow in the conductor on the basis of these values.

Referring to fig. 3, a preferred embodiment of the directional detector is illustrated. The capacitive measurement of voltage is carried out by a capacitive coupling between a metal panel 20 and the conductor 10.

The metal panel 20 is curved so that it resembles the shape of the conductor 10 and is in close proximity which ensures high capacitance in the capacitive coupling. The metal panel 20 is preferably rectangular in shape with an area between 4 to 6 cm^2 of metal panel mounted a few millimeters over the conductor 10. Other shapes and sizes of the metal panel 20 are naturally also possible.

The current-measuring circuit comprises one or more magnetic field detectors 14 for detection of the magnetic field generated by the current flow in the conductor 10. The magnetic field detector 14 is preferably a hall element 15, 16 placed in close proximity to the conductor. The hall element provides a voltage level proportionate to the current in the conductor.

To avoid or minimise interference from external magnetic fields, it is preferable to use double hall elements instead of single hall elements. This will cancel out interference fields because the first hall element will detect the interference fields in one direction and the second hall element will detect the interference fields in the opposite direction resulting in a measured value of nil. Examples of external magnetic fields are the Earth's magnetic field and magnetic fields from conductors or components placed close to the detector.

The detected values are led to the calculation circuit 17 placed in a circuit board 23. To avoid any magnetic fields generating voltage in the supply lines 22 for the magnetic field detectors 14, the lines are surrounded by shields 21 connected to a ground potential. The shields

21 also protect the circuit board 23 containing the calculation circuit 17.

The isolation of the entire detector in relation to high-voltage is obtained by embedding the entire circuit in silicone rubber. At the same time, the silicone is used as a dielectric between the metal panel and the conductor. The voltage providing cable and the ground cable from the construction are led through an isolating silicone tube into the silicone-protected circuit. Thus, the construction becomes protected from an electrical point of view.

The cables will normally be shielded to avoid any generation of interfering magnetic fields in close proximity to the detectors.

The calculation circuit 17 generates information concerning the energy direction either through an optic fiber to e.g. a control center or on a display 18 comprising e.g. a couple of light-emitting diodes (LEDs) indicating an energy flow in one direction or the other.

The voltage often falls out in case of short-circuiting. This is the reason why the calculation circuit 17 simulates the voltage in 1 or 2 seconds subsequent to the detection of a fault in the conductor. In this manner, it is still possible to compare the polarity of the recorded short-circuit current with the polarity of the voltage. The direction of the short-circuit current is determined by the calculation circuit 17 within the first two periods after a current increase above a certain trigger level.

The energy supply takes place from an external voltage source. This voltage source must provide a DC voltage of 9 to 12 volts in such a manner that the DC-ground is galvanically separated from the ground potential. The circuit also requires voltage in the short-circuit situation where the voltage supply from the short-circuited net cannot be expected. This is the reason why the external voltage supply must feature a back-up battery. With the protected construction of the measuring unit, it is possible to replace the battery (approx. every 10 years) without interrupting the high voltage.

Referring to fig. 5, the calculation circuit samples the signals a number of times per period, presently set at 20 times per period. The exact current I and voltage U, i.e. value and polarity, are read at each sampling. Due to the frequent samplings, it is possible to determine quite accurately when the zero-crossing (phase change) of the voltage takes place. Once the voltage polarity has been determined, it is possible to determine the sample numbers of a period to provide a comparison of the polarities of the current and the voltage.

In a preferred embodiment of the invention, the relative direction of the energy is determined by a simple mathematical multiplication of the polarities of the current and the voltage at a given point in time between the zero-crossings.

The detector will determine the direction of the energy flow when a high current level above a certain limit is detected.

The polarity of the current is measured and subsequently compared with the polarity of the voltage (whether actually measured or simulated) and the energy direction is determined. One or more of the zero-crossings of the voltage or current can be simulated as well as measured.

Referring to fig. 6, the algorithm is designed in such a manner that once the voltage is above the positive noise limit, it is checked whether a zero-crossing has taken place immediately before that. If the preceding voltage (from the preceding sampling) is below a positive noise limit, a closer examination is made. If the voltage is below the negative noise limit 4/20 periods earlier (4 samples ago), a zero-crossing has taken place.

The sample number for the exact zero-crossing point in time must now be somewhere between the current sample X and the 4/20 previously made sample X-4. If the value of the sample X-3 is below the negative noise limit, the zero-crossing is at X-1 or X-2. Of the two samples, the sample closest to zero is chosen irrespective of the noise limit. If the value for X-3 is above the negative noise limit, X-2 is chosen as the zero-crossing value.

Despite the above-mentioned algorithm, there is still a minimal risk of the determination of the zero-crossing being incorrect in a noise-filled reading environment. This is the reason why the algorithm has a built-in phase-locked loop circuit so that two succeeding zero-crossing points may not deviate more than certain period (e.g. 4/20) from each other during their respective periods.

With this algorithm, it is possible to make an accurate determination of the zero-crossing point in time irrespective of the noise level in the measuring system.

It is understood that the algorithm is capable of determining the zero-crossing at a negative to positive voltage crossing (illustrated in fig. 6) as well as a positive to negative crossing.

Those skilled in the art will appreciate that the present invention is not limited to the detection of an energy flow direction in the event of a fault on a high-voltage transmission and distribution system. Detection and indication of an energy flow direction in a normal working state is also possible as well as indication of an energy flow direction on other high-voltage systems involving an energy flow in a conductor.

Also a directional detector for low-voltage systems is possible, such as a portable detector for household cabling, making it possible to trace defects in the cabling causing a current which is higher than in a normal working state. The current and voltage detectors may preferably be of different types than the ones described above. Especially because of the low-current values, magnetic-resistant detectors may replace the hall elements in an advantageous manner. The method of measuring voltage with a capacitive detector may also advantageously be replaced by methods involving direct contact to the conductor.

List

1. Generator
2. Transmission or distribution system consisting of underground cables or overhead lines
3. Electric consumers or loads
4. Directional indicators
5. Directional detectors
6. Electrical fault e.g. a short-circuit

10. Conductor
11. Capacitive detector
12. Capacitor
13. Reference potential e.g. ground potential
14. Electromagnetic field detector
15. First electromagnetic field detector element
16. Second electromagnetic field detector element
17. Calculating circuit
18. Directional indicator

20. Metal panel
21. Shield for electromagnetic field
22. Supply lines to the electromagnetic field detectors
23. Circuit board containing the calculation circuit

30. X-axis in degrees (°)
31. Y-axis in absolute values (U/U and I/I)
32. Noise level

U. Voltage
I. Current
Tr. Transformer
Hv. High-voltage cable or line
X, X-1, …. Samples of the X-axis

Patent Claims

1. Directional high-voltage detector (5) for a high-voltage conductor (10) comprising

- at least one voltage-measuring circuit for measuring voltage in said conductor (10),
- at least one current-measuring circuit for measuring current in said conductor (10),
- and means for determining the energy flow in the conductor (10) on the basis of measurements made by said voltage-measuring circuit and said current-measuring circuit,

characterised in that

said means determine the energy flow direction on the basis of the polarities of the current and voltage between two zero-crossings of the voltage or the current.

2. Directional high-voltage detector according to claim 1, characterised in that the voltage-measuring circuit comprises at least one capacitive detector (11) which forms a capacitive coupling with the conductor (10).

3. Directional high-voltage detector according to claim 2, characterised in that the capacitive detector (11) comprises a metal plate (20) covering a section of the conductor (10) partially or totally.

4. Directional high-voltage detector according to claim 3, characterised in that the edges or corners of the plate are bent away from the conductor (10).

5. Directional high-voltage detector according to claim 1, characterised in that the dielectric material between the metal plate (20) and the conductor (10) is silicone covering the surface of said detector partially or totally.

6. Directional high-voltage detector according to claim 5, characterised in that the silicone layer serves as an isolation layer between the high-voltage potentials in said detector and the exterior, respectively.

7. Directional high-voltage detector according to claim 1, characterised in that at least one capacitor (12) is connected serially to the capacitive coupling (11) and a reference potential (13), respectively.

8. Directional high-voltage detector according to claim 7, characterised in that the reference potential (13) is the ground potential of at least one conductor.

9. Directional high-voltage detector according to claim 1, characterised in that the current-measuring circuit comprises at least one detector (14) for measuring the magnetic field generated by the current in the conductor (10).

10. Directional high-voltage detector according to claim 1, characterised in that the magnetic field detector (14) comprises two hall elements (15, 16).

11. Directional high-voltage detector according to claim 1, characterised in that the supply lines for the magnetic field detector (15, 16) and the calculation circuit (17) comprise shields (21) against magnetic fields.

12. Directional high-voltage detector according to claim 1, characterised in that said means (17) determine the energy flow in the conductor (10) on the basis of measurements by said voltage-measuring circuit and said current-measuring circuit.

13. Directional high-voltage detector according to claim 12, characterised in that said means (17) determine the energy flow direction on the basis of the polarities of the current and voltage between two preceding zero-crossings of the voltage.

14. Directional high-voltage detector according to claim 1, characterised in that the magnetic field detector (14) comprises at least one magnetic-resistant detector (15, 16).

15. Method for determining the direction of an energy flow in a high-voltage conductor wherein at least one voltage-measuring circuit measures voltage in said conductor by means of at least one capacitive detector, at least one current-measuring circuit measures current

in said conductor by means of a magnetic field detector and a calculation circuit calculating a direction value on the basis of the polarities of the current and the voltage between two zero-crossings of the voltage or the current.

16. Method for determining the direction of an energy flow in a high-voltage conductor according to claim 15, characterised in that the calculation circuit calculates the direction value on the basis of the polarities of the current and the voltage between two preceding zero-crossings of the voltage.

17. Method for determining the direction of an energy flow in a high-voltage conductor according to claim 15, characterised in that a calculation circuit divides said voltage into a number of samples within a period of time and where said calculation circuit compares the first voltage sample value numerically larger than a constant value with the immediately preceding values to determine the sample value closest to zero voltage.

18. Method for determining the direction of the energy flow in a high-voltage conductor according to claim 17, characterised in that the calculation circuit calculates the direction value on the basis of the polarities of the current and voltage between two preceding zero-crossings of the voltage.

19. Method for determining the direction of the energy flow in a high-voltage conductor according to

claim 18, c h a r a c t e r i s e d i n that the constant value exceeds the noise level.

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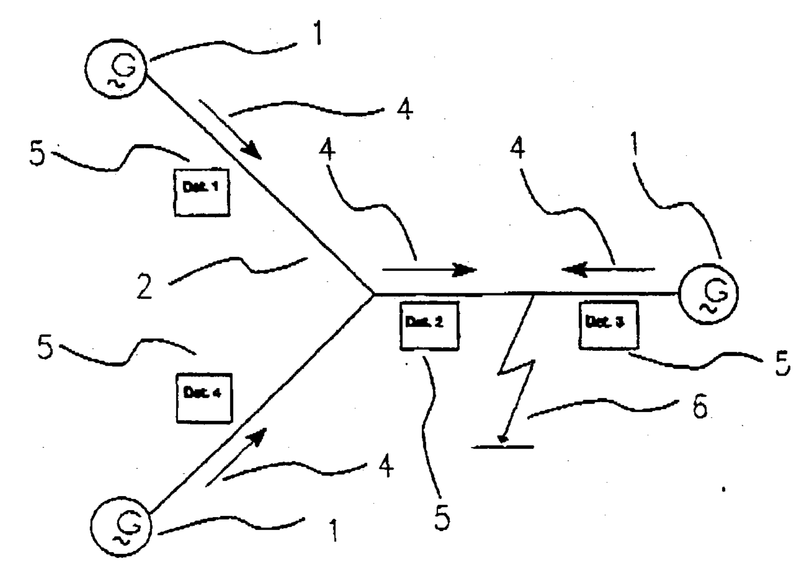
(54) Title: DIRECTIONAL HIGH-VOLTAGE DETECTOR



(57) Abstract: Directional high-voltage detector for a high-voltage conductor comprising at least one voltage-measuring circuit for measuring the voltage in said conductor, at least one current-measuring circuit for measuring the current in said conductor and means for determining the energy flow in the conductor on the basis of the measurements made by said voltage-measuring circuit and said current-measuring circuit.

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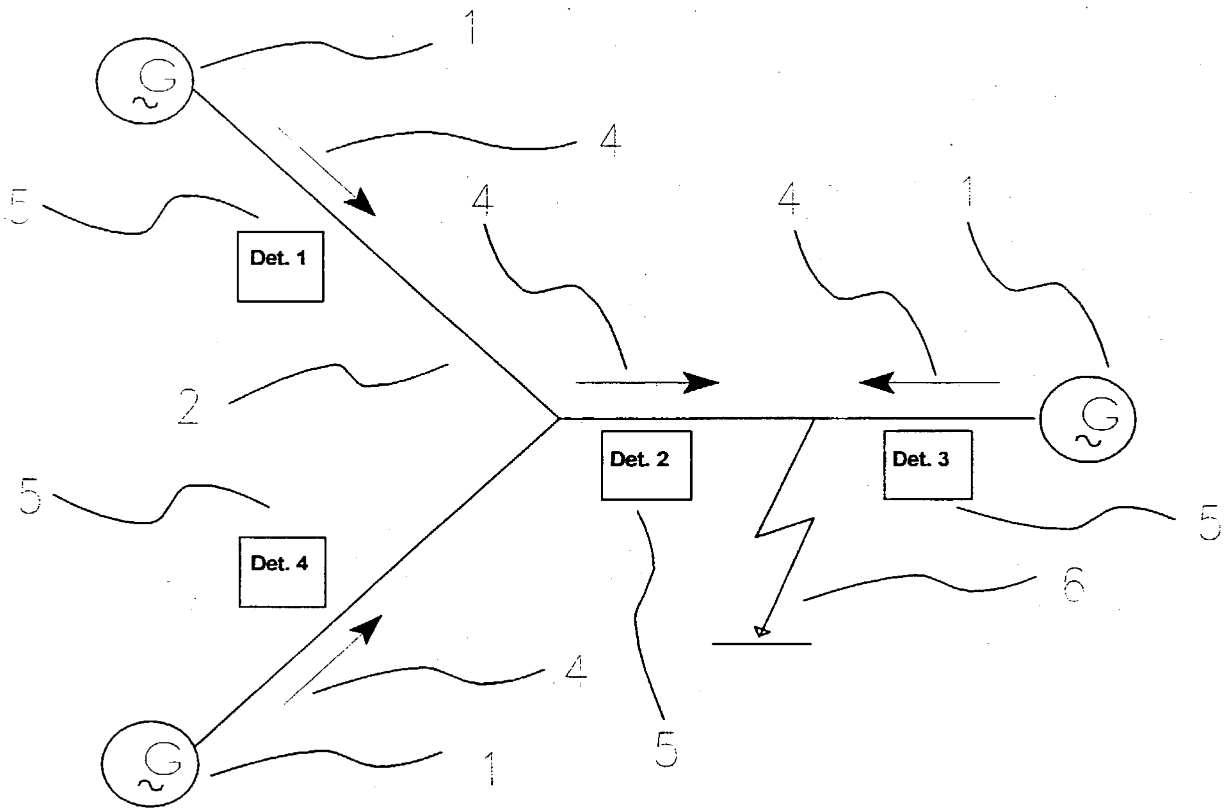

Fig. 1

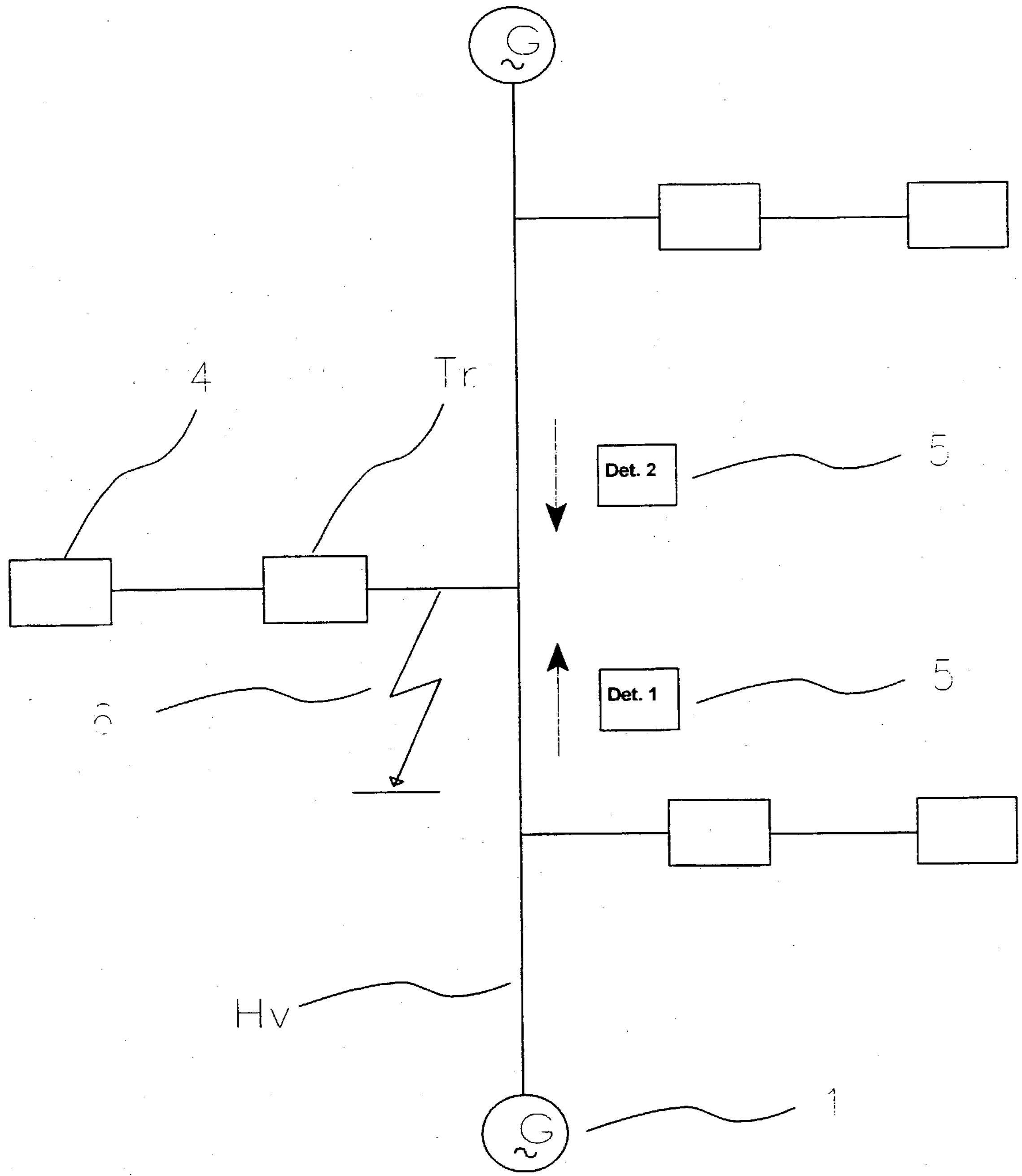

Fig. 1a

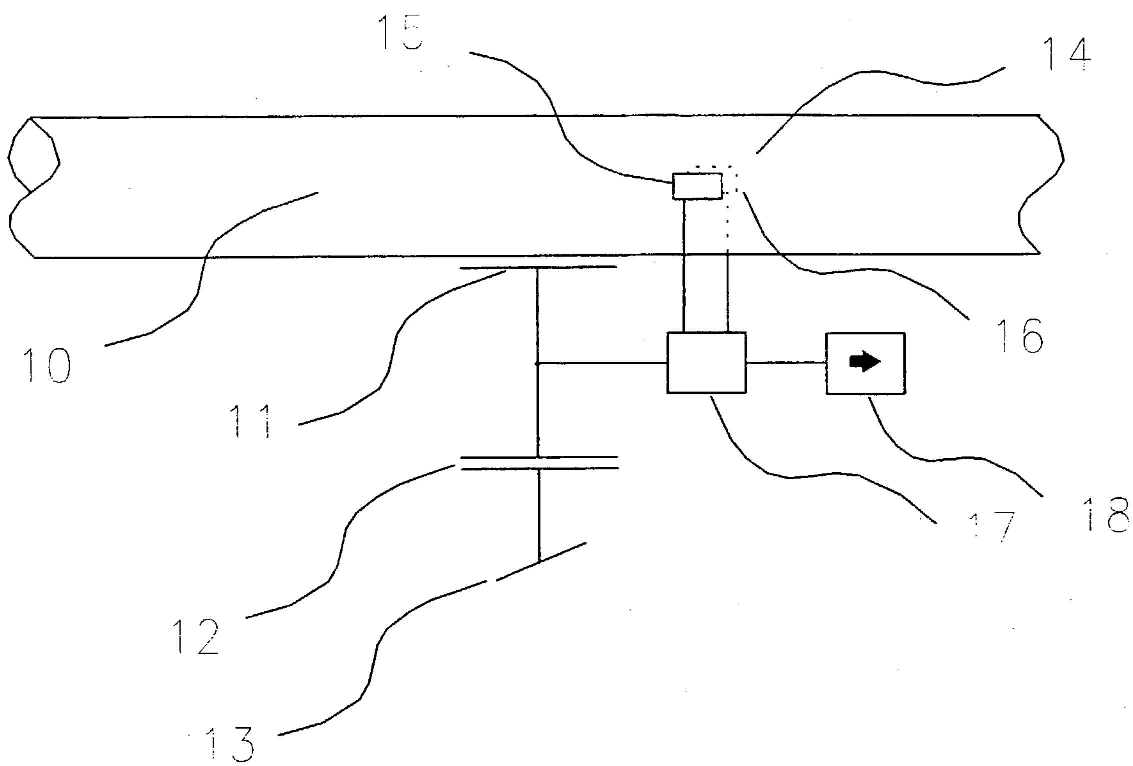

Fig. 2

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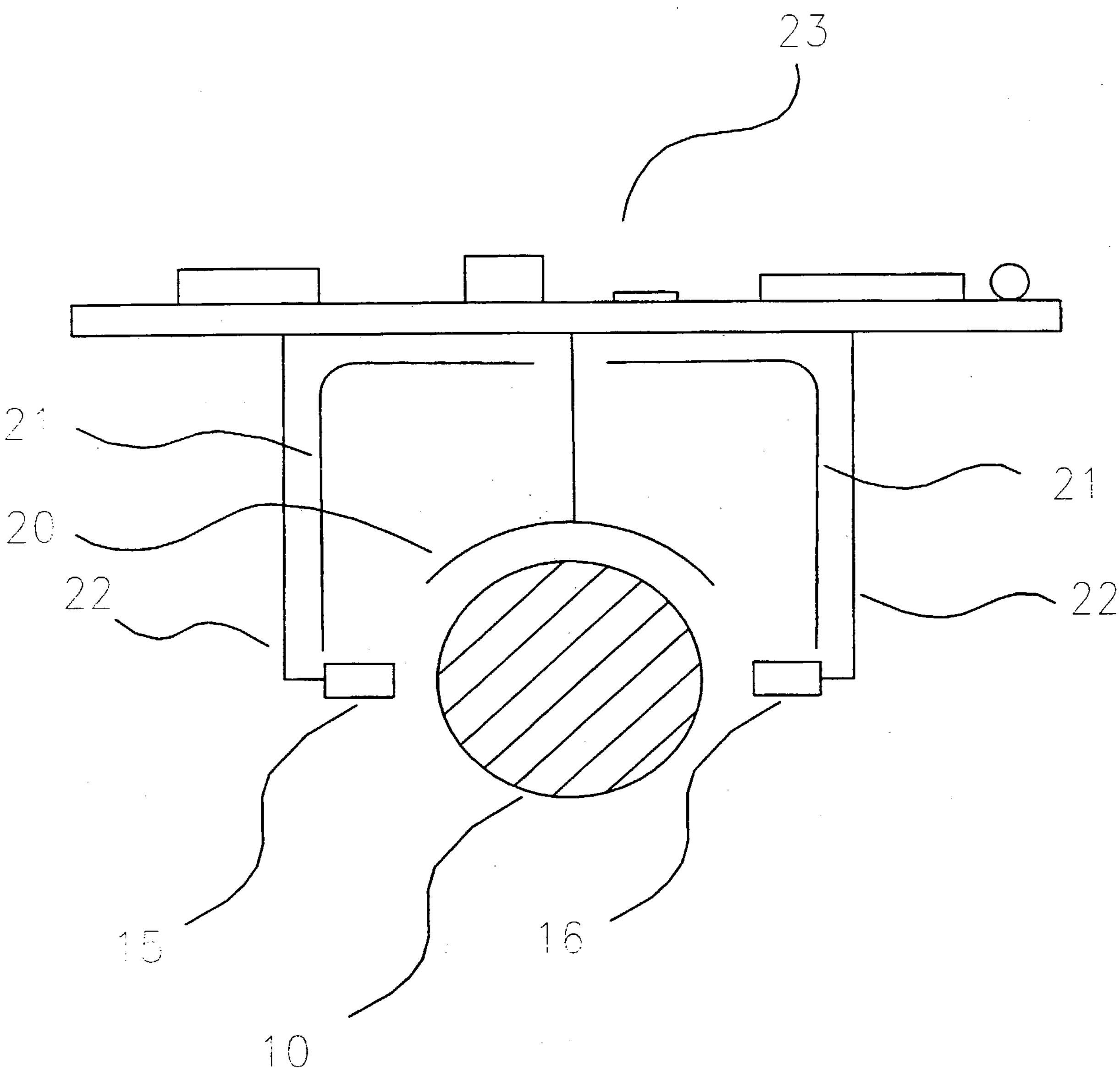

Fig. 3

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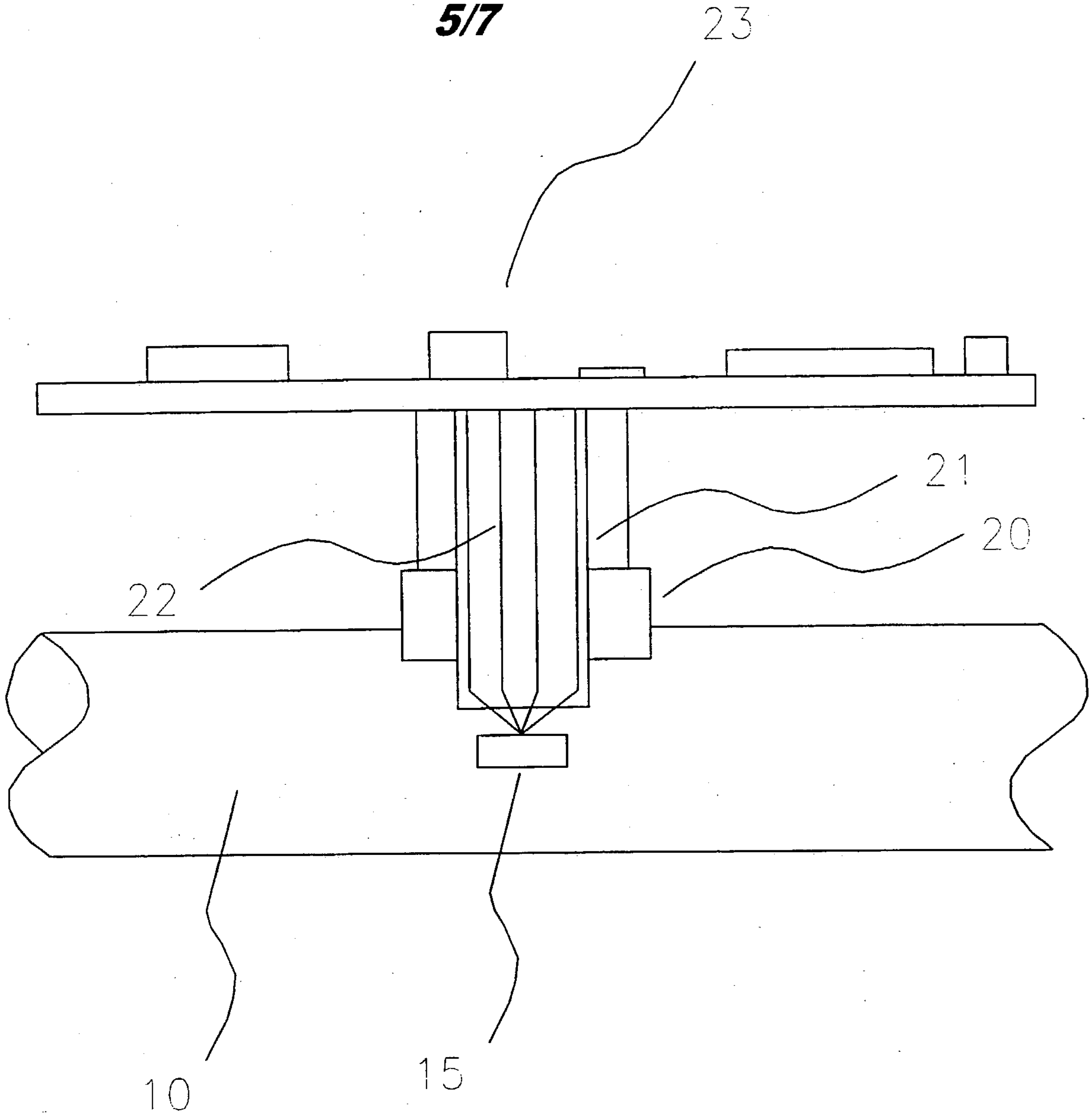

Fig. 4

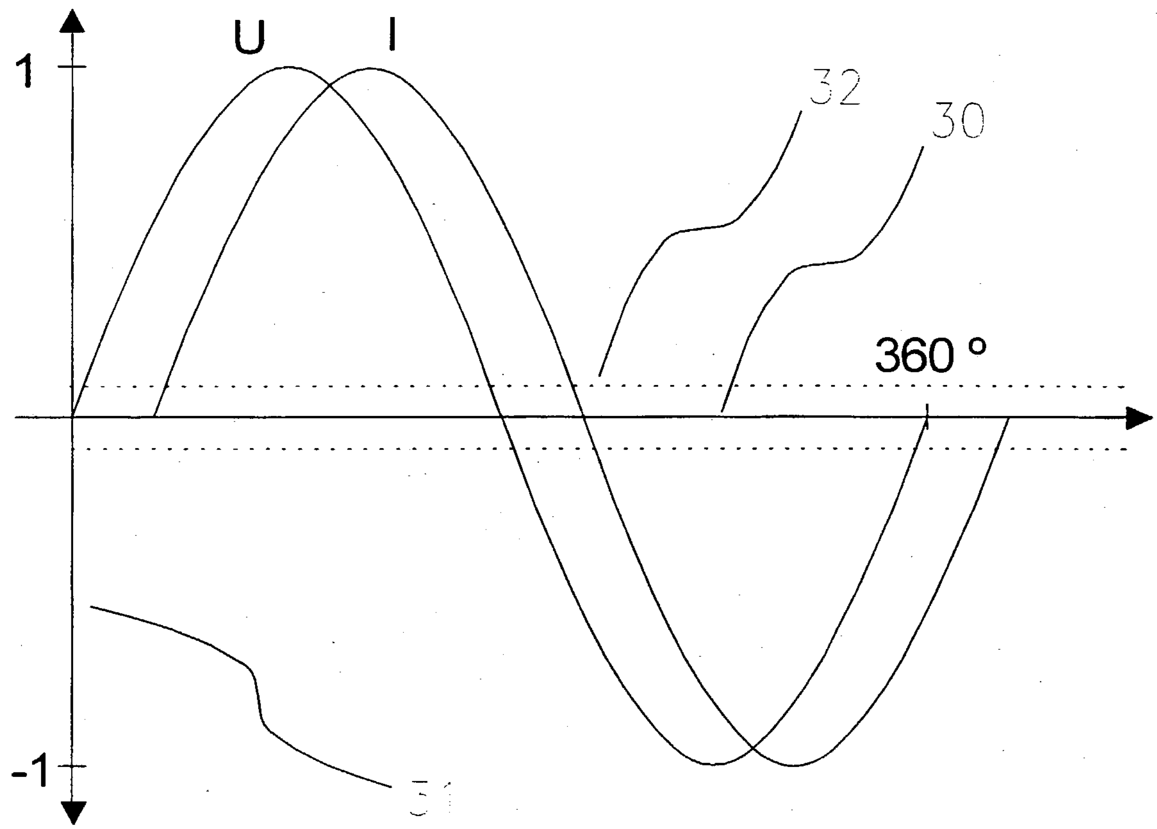

Fig. 5

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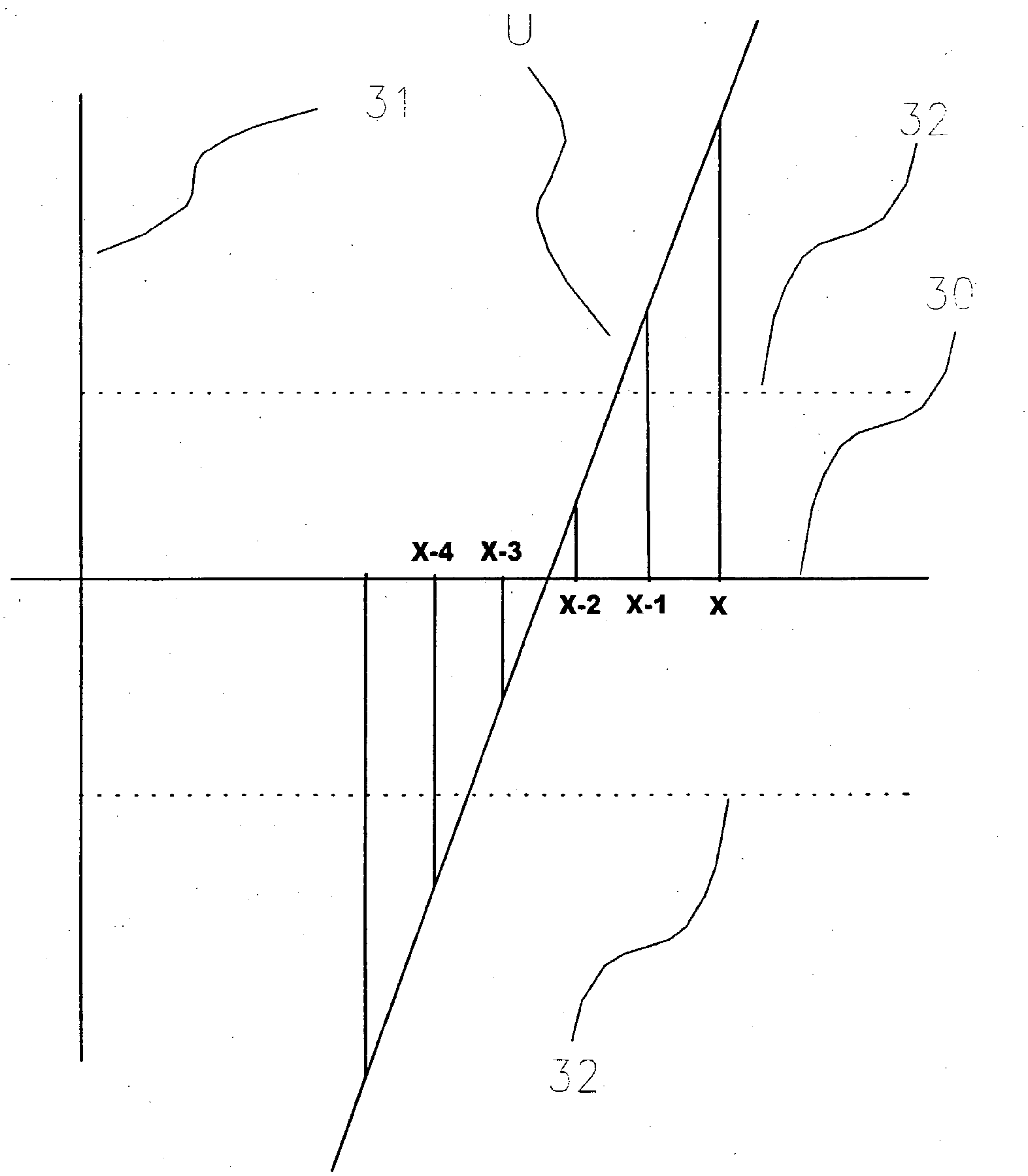

Fig. 6

DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my/our name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled DIRECTIONAL HIGH-VOLTAGE DETECTOR the specification of which

(check one)

_____ is attached hereto.

_X_ was filed on 11 January 2002 as

Application Serial No. 10/030,675

and was amended on _________

(if applicable)

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, 1.56(a).

I hereby claim foreign priority benefits under title 35, United States Code 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s).

(Number)	(Country)	(Day/Month/Year Filed)	Priority Claimed
PA 1999 01010	Denmark	12 July 1999	**Yes** No
99203602.0	EPO	27 October 1999	**Yes** No

(Number) (Country) (Day/Month/Year Filed)

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
PCT/DK00/00376	7 July 2000	Pending

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

PROVISIONAL APPLICATION NUMBER	FILING DATE

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

23413
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Full name of sole
or first inventor: JOHANSEN, Oluf Peter Kaad

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1-00

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